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Summary

Corrugated fiberboard containers were made from nominal 42-pound starch surface-sized linerboard consisting of 50 percent high-yield kraft pulp from Colombian hardwoods and 50 percent western kraft softwood pulp, and 26-pound corrugating medium made from 100 percent high-yield kraft Colombian hardwood screenings. The containers did not have as high a compressive strength as containers used for controls. The combined board as well as the linerboards were slightly low in bursting strength. Corrugating medium made from NSSC pulp fractured when fluted on the singlefacer at 20 feet per minute and minimum tension. Screened pulp from high-yield digestions (Kappa 85.0) had about 30 percent less bursting strength and tearing resistance than the fully cooked pulp (Kappa 24.7) and about 20 percent less tensile strength.

1/ Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

Experimental

Wood Mixture

Seventeen species of Colombian hardwoods were used to make kraft and NSSC pulps for linerboard and corrugating medium paper machine trials. The chips were made from bark-free wood in a commercial-size, four-knife chipper. The nominal length of the chips was 5/8 inch, and the fines and oversize were removed prior to blending of the individual species to obtain the mixture. The names, specific gravities, and amounts of the 17 species in the mixture are listed in table 1.

Kraft Pulping

Based on the results of preliminary kraft pulping studies made earlier and reported in AID Report No. 8, "Exploratory Kraft and NSSC Pulping and Production of a Bleached, Market-Grade, Kraft Pulp from Colombian Hardwood Mixtures," two series of pilot-scale digestions were made--fully cooked kraft and high screenings kraft. In the first series, two pilot-scale digestions were made to provide fully cooked slush pulp for linerboard production. The following conditions were used:

(1) 16.0 percent active alkali.

(2) 25 percent sulfidity.

(3) 4-to-1 water-to-wood ratio.

(4) 90 minutes to raise the temperature to 170° C.

(5) 75 minutes at 170° C.

Chips with a dry weight of 140 pounds were used in each pilot-scale digestion. At the end of cooking, the digester was blown, and the

resulting pulps were washed, screened through a 0.012-inch slotted flat screen, and wet lapped. The composite screened pulp had a Kappa number of 24.7.

Six identical pilot-scale digestions were made to provide both a screened pulp for use in linerboard and screenings for use in corrugating medium. The conditions used were the same as those of the first series except for time at 170° C, which was reduced to only 5 minutes. As with the fully cooked digestions, these digestions were similarly blown, washed, screened, and wet lapped. The screenings were subsequently fiberized at 18 percent consistency to a Canadian Standard freeness of about 700 milliliters and refined at 12 percent consistency to a freeness of about 350 milliliters, both in a 36-inch-diameter, double-rotating disk mill. The composite screened pulp had a Kappa number of 85.0, while the composite pulp from the fiberized screenings had a Kappa number of 130.

NSSC Pulping

Again, based on the results of preliminary NSSC pulping studies made earlier and reported in AID Report No. 8, two pilot-scale digestions were made to obtain a pulp yield of about 75 percent. The following conditions were used:

(1) 16.0 percent sodium sulfite.

(2) 4.0 percent sodium carbonate.

(3) 3.5-to-1 water-to-wood ratio.

(4) 15 minutes' presteaming of the chips at 15 pounds per square inch.

(5) 120 minutes to raise the temperature to 175° C.

(6) 90 minutes at 175° C.

At the end of cooking, the liquor was blown from the digester. The cooked chips were fiberized and refined the same as the high-yield kraft screenings.

Papermaking

The kraft pulps were converted into 42-pound-per-1,000-square-foot linerboard on an experimental Fourdrinier paper machine. Two nominal 26-pound-per-1,000-square-foot corrugating mediums were made--one from the NSSC pulp and the other from the screened rejects of the high-yield kraft cooks.

Converting

Runnability.--The corrugating mediums were evaluated for resistance to fracturing on the FPL singlefacer by increasing the speed from 0 to 600 feet per minute with a minimum web tension and then increasing the web tension at a constant web speed of 600 feet per minute.

Bonding.--Conventional Stein-Hall starch corrugating adhesive was used to combine the linerboards to the fluted corrugated medium. Pin adhesion tests were conducted to evaluate the bond strength.

Scoring.--Each of the combined boards was subjected to three-point roller scoring (wheel clearance, 0.031 in.) after the combined boards were conditioned at 80° F, 30 percent relative humidity; 73° F, 50 percent relative humidity; or 80° F, 90 percent relative humidity. After scoring, each scoreline made perpendicular to the flutes was evaluated by bending

the material on one side of the scoreline back 90 degrees and then forward 180 degrees and measuring the amount of visual cracking. The scorelines made parallel to the flutes were evaluated by bending forward 180 degrees and backward 90 degrees and then measuring the amount of visual cracking.

Containers.--The combined board was roller scored (wheel clearance, 0.052 in.), slotted, and formed into containers using a stapled manufacturer's joint. The containers were 10-3/4 inches long, 8-1/16 inches wide, and either 3-1/4 or 8 inches high. The 8-inch containers had short flaps due to the 12-inch width limitation of the paper machine. The containers were tested in top-to-bottom, side-to-side, and end-to-end compression. The impact resistance of the containers was determined using a container 10-3/4 by 8-1/16 by 3-1/4 inches filled with a 12-pound metal can load. These containers were dropped from various heights on the container edge diagonally opposite the manufacturer's joint. The impact resistance was determined as the height at which half the containers would be expected to fail and half would not. A container was considered failed if any of the load was spilled or if a horizontal scoreline was split its entire length.

Results

Pulp Properties

The handsheet properties of the screened kraft pulps are given in table 2. The bursting and tensile strengths of the fully cooked kraft pulp with a Kappa number of 24.7 were about the same as those found

earlier from small-scale digestions of the same mixture. The tearing resistance of this pilot scale fully cooked kraft pulp was about 15 percent higher than that of the similar small-scale pulp reported in AID Report No. 8. The screened pulp from the high-yield digestions with a Kappa number of 85.0 had about 30 percent less bursting strength and tearing resistance than the fully cooked pulp and about 20 percent less tensile strength.

The handsheet properties of the fiberized and refined kraft screenings and NSSC pulps were not determined.

Paperboards

The results are given in table 3. Without starch surface treatment the linerboards were low in most strength properties. The starch improved the burst as much as 30 percent, but still this did not produce linerboard with 100 burst. The boards with the high-yield kraft pulp (7161, 7162) had better compressive strength than those made with the lower yield pulp (7187, 7188). In other strength properties the latter boards were generally better. Lowering the freeness 65 milliliters (7189) had little or no effect on properties.

The results on the medium indicate that a satisfactory medium can be made from 100 percent NSSC Colombian hardwoods in terms of strength properties such as ring crush and Concora medium test (CMT). Unfortunately, this NSSC medium could not be run on the singlefacer without severe cracking at 20 feet per minute and minimum tension. Thus, it was not converted into corrugated fiberboard containers.

The medium (7160) made from the screening rejects from the high-yield kraft cook had lower CMT and ring crush than the NSSC medium (7157). This kraft medium ran without fracturing on the corrugator at 400 feet per minute and 1.0 pound per lineal inch of web tension. Thus, this medium was combined with the linerboard made from the high-yield pulp furnish (7161) and the linerboard made from the high-yield pulp furnish and surface sized with 2.1 percent cornstarch (7162).

Combined Board

Results of the evaluation of the combined board are given in table 4. As expected from the linerboard properties, the burst of the combined board was well below 200 for the material made with high-yield pulp and not surface sized. Nor did the combined board with the starch surface-sized facings meet the minimum burst requirement. The flat-crush values and the edgewise compressive strength, as measured by the short column tests of the starch-treated material, were low. The effect of moisture content on edgewise compressive strength was in line with previous work. Flexural stiffness of the experimental material, although direction dependent, was approximately equal to the control, which would be expected from the modulus of elasticity values of the component paperboards.

None of the material exhibited scoreline cracking when scored and folded perpendicular to the flutes. For the scores made parallel to the flutes, the experimental materials were more susceptible to cracking than the control; however, increasing the moisture content or the score wheel clearance significantly reduced the cracking. The starch-treated material cracked more than the untreated material. This was in line

with what might be expected based on the stiffness of the two materials. No cracking was encountered in the scoring of the corrugated for the containers when the score wheel clearance was 0.052 inch and the atmospheric conditions were 73° F, 50 percent relative humidity.

Containers

The compressive and impact properties of the containers are given in table 5. Again, the compressive strength of the containers made from both the starch-treated and untreated material was lower than the control. Only the starch-treated containers were better in impact resistance than the control.

Conclusions

(1) Corrugating medium made from 100 percent high-yield kraft screenings can be fluted and combined with linerboard made from a mixture of 50 percent high-yield kraft Colombian hardwood screened pulp and 50 percent western softwood unbleached kraft pulp.

(2) Corrugated fiberboard containers can be made from nominal 42-pound, starch surface-sized linerboard consisting of 50 percent high-yield kraft Colombian hardwood screened pulp and 50 percent western kraft softwood pulp, and 26-pound corrugating medium made from 100 percent high-yield kraft Colombian hardwood screenings.

(3) The corrugating medium made from the NSSC pulp fractured when fluted on the singlefacer at 20 feet per minute and minimum tension, thus indicating a potential problem with the utilization of tropical hardwood NSSC pulp in medium.

Table 1.--Names, specific gravities, and amounts of Colombian hardwoods in the mixture used to make kraft and NSSC pulps

Species			Specific gravity[1/]	Amount[2/]
No.	Common name	Botanical name		
				Pct
1	Ceiba	Ceiba pentandre	0.225	8.33
2	Yarumo	Cecropia sp.	.250	8.33
3	Cirpo	Pourouma sp.	.369	8.33
4	Chingale	Jacaranda copaia	.372	8.33
5	Dormilon	Vochysia ferruginea	.447	5.56
6	Sande	Brosimum utile	.494	5.56
7	Sangretoro	Virola sebifera	.511	5.56
8	Arenillo	Catostemma alstonii	.536	5.56
9	Canelo	Nectandra sp.	.546	5.56
10	Perillo negro	Couma macrocarpa	.547	5.56
11	Casaco	Hieronyma sp.	.603	5.56
12	Carbonero	Enterolobium schomburgkii	.634	5.56
13	Chocho	Ormosia paraensis	.671	5.56
14	Carreto	Aspidosperma sp.	.692	4.17
15	Lecheperra	Helicostylis tomentosa	.785	4.17
16	Tamarindo	Dialium guianense	.823	4.17
17	Caimo	Pouteria sp.	.859	4.17

1/ Dry weight, green volume basis.
2/ Moisture-free wood basis.

Table 2.--Handsheet properties of screened kraft pulps made from mixed Colombian hardwoods

Kappa No.	Freeness (Canadian Standard)	Beating time	Burst factor	Tear factor	Breaking length	Apparent density
	Ml	Min			Km	G/cm^3
	SCREENED PULP FROM FULLY COOKED DIGESTIONS					
24.7	600	3	29	130	6.4	0.52
	500	15	47	147	8.4	.56
	400	22	55	159	9.3	.59
	300	28	60	158	9.9	.61
	SCREENED PULP FROM HIGH-YIELD DIGESTIONS					
85.0	600	11	23	106	5.4	.50
	500	26	31	109	6.6	.53
	400	34	38	112	7.5	.54
	300	42	44	112	8.3	.55

Table 3.--Properties of linerboard and corrugating medium made from Colombian tropical hardwood

Machine run No.	Stuff freeness (CS)	Starch pickup[1/]	Properties[2/]																	
			Weight		Thickness	Density	Bursting strength	Tearing resistance		Folding endurance		Ring crush		Concora (CMT)	Tension					
															Maximum stress		Modulus of elasticity		Strain to failure		Thickness[3/]
			Square meters	1,000 square feet				MD	CD	MD	CD	MD	CD		MD	CD	MD	CD	MD	CD	
	Ml	Pct	G	Lb	Mil	G/cm^3	Pt	G	G	Double folds	Double folds	Lb	Lb	Lb	Lb/in.^{2}	Lb/in.^{2}	1,000 lb/in.^{2}	1,000 lb/in.^{2}	Pct	Pct	Mil
								LINERBOARD[4/]													
Control[5/]	500	--	205.0	42.0	12.2	0.66	114	313	328	408	432	152	112	--	8,420	3,680	864	378	2.2	6.3	11.4
7161	520	--	209.6	43.0	12.4	.67	66	322	370	942	533	113.0	87.5	--	5,870	3,180	994	407	1.5	3.3	11.2
7162	520	2.1	212.9	43.6	11.9	.70	88	346	352	1,035	913	134.1	107.9	--	7,080	3,790	1,288	444	1.7	4.2	11.1
7187	525	--	205.0	42.0	11.8	.69	73	361	370	1,186	519	96.0	73.5	--	5,410	3,530	915	420	1.6	3.9	10.5
7188	525	3.5	205.1	42.0	11.6	.70	91	337	340	1,229	919	114.2	95.3	--	7,070	4,110	1,023	467	1.8	4.8	10.9
7189	460	--	205.1	42.0	11.8	.68	68	365	360	1,095	820	95.1	78.6	--	6,070	3,410	886	434	2.0	3.5	10.6
								CORRUGATING MEDIUM[6/]													
7160[7/]	290	--	122.9	25.2	9.2	.52	33	108	110	57	36	62.9	47.8	53.0	4,380	2,550	620	310	1.6	3.7	8.1
7157[8/]	350	--	126.9	26.0	9.5	.52	42	92	106	34	35	72.4	56.4	67.1	5,170	2,890	650	315	2.1	3.3	8.2

1/ A 10 pct solution of cornstarch was added at horizontal size press.
2/ All tests according to TAPPI standard methods except as indicated. MD = machine direction; CD = cross direction.
3/ Thickness measurements made using the procedure described by Setterholm (Tappi, Vol. 57, No. 3, March 1974).
4/ All furnishes contained 50 pct Colombian hardwood kraft and 50 pct western softwood kraft. Both pulps refined separately in conical refiner. Each furnish treated with H_2SO_4 to pH 7.0, 1.0 pct rosin size and then pH adjusted to 5 with alum.
5/ 100 pct southern pine kraft.
6/ All furnishes 100 percent Colombian hardwoods refined in 36-in. double disk and in 12-in. pressurized disk refiners.
7/ Kraft screenings.
8/ Neutral sulfite semichemical.

Table 4.--Physical properties of the combined board made from high-yield Colombian hardwood kraft[1/]

Starch	Basis weight	Burst		Pin adhesion: Singleface side		Pin adhesion: Doubleface side		Flat crush		Short column compression: 80° F, 30 percent relative humidity		Short column compression: 73° F, 50 percent relative humidity		Short column compression: 80° F, 90 percent relative humidity		Flexural stiffness[2/]: Parallel to length		Flexural stiffness[2/]: Perpendicular to length		Scoreline cracking[3/]: 80° F, 30 percent relative humidity	Scoreline cracking[3/]: 73° F, 50 percent relative humidity	Scoreline cracking[3/]: 80° F, 90 percent relative humidity
										Lb/in.	CV	Lb/in.	CV	Lb/in.	CV	Lb/in.	CV	Lb/in.	CV			
Pct	Lb/1,000 ft^2	Pt	CV[4/]	Lb/in.	CV	Lb/in.	CV	Lb/in.^{2}	CV											Pct	Pct	Pct
100 PERCENT SOUTHERN PINE (CONTROL)																						
0	130.0	257	7.7	3.76	8.8	6.90	7.4	27.4	5.7	--	--	63.7	2.2	30.9	4.2	109.0	3.0	230	8.6	19.7	3.1	0
7161/7160/7161[5/]																						
0	126.6	135	5.7	4.99	20.6	6.09	18.5	20.7	2.3	53.5	7.05	48.5	4.45	22.2	5.6	117.2	4.3	202	6.83	22.7	0	0
7162/7160/7162																						
	129.9	171	8.6	5.35	17.4	5.75	13.4	21.3	2.6	61.2	5.4	54.0	3.6	29.5	3.7	134.3	5.7	233	8.4	44.7	4.6	0

1/ All conditioning and testing done at 73° F, 50 pct relative humidity except where noted.
2/ 4-point bending: flutes parallel and perpendicular to specimen length.
3/ Scoreline wheel clearnace: 0.031 in. for tests, 0.052 in. for boxes.
4/ CV = coefficient of variance = pct.
5/ Papermachine run numbers; full description given in tables 3 and 4.

Table 5.--Properties of containers made from high-yield Colombian hardwood kraft[1/]

Starch	Top-to-bottom compression[2/]								Side-to-side compression				End-to-end compression				Impact resistance[3/]
	8-inch-high containers				3-1/4-inch-high containers				3-1/4-inch-high containers				3-1/4-inch-high containers				
	Load	Coefficient of variation[4/]	Deformation	Coefficient of variation	Load	Coefficient of variation	Deformation	Coefficient of variation	Load	Coefficient of variation	Deformation	Coefficient of variation	Load	Coefficient of variation	Deformation	Coefficient of variation	
Pct	Lb	Pct	In.	Pct	Lb	Pct	In.	Pct	Lb	Pct	In.	Pct	Lb	Pct	In.	Pct	In.
100 PERCENT SOUTHERN PINE (CONTROL)																	
0	917	8.5	0.82	7.0	676	6.1	0.45	16.3	412	8.7	0.34	36.7	283	5.8	0.26	15.4	81
									7161/7160/7161[4/]								
0	570	7.4	.57	4.1	478	4.6	.43	4.1	332	11.8	.40	29.3	218	6.4	.32	25.8	77
									7162/7160/7162								
2.1	703	8.4	.68	16.7	560	6.0	.45	6.4	373	11.8	.36	21.9	252	10.7	.31	21.7	94

1/ All conditioning and testing done at 73° F, 50 pct relative humidity.
2/ Containers were 10-3/4 by 8-1/16 in. in perimeter (length x width).
3/ Single drop of container with 12-lb can load.
4/ Paper machine run numbers; full description given in tables 3 and 4.